Letter

Carbon Nanotube Preparation by Arc Discharge Method in Various Gases

Member Hirofumi Takikawa (Toyohashi University of Technology)
Student-member Aristotle M. Coronel (Toyohashi University of Technology)
Member Tateki Sakakibara (Toyohashi University of Technology)

Multi-wall carbon nanotubes were synthesized by dc carbon arc discharge method in various ambient gases such as He, H_2, N_2, O_2, C_2H_2, and CO_2, and at different pressures (3-100 kPa). The appearance of the nanotubes and nanoparticles on the cathode surface varied with respect to these experimental parameters. The remarkable conditions, in which considerable amount of nanotubes prepared with the fewest nanoparticles, were obtained in both H_2 and O_2 ambient at 25 kPa and 100 A.

Keywords: carbon arc discharge method, multi-wall carbon nanotubes, nanoparticles, ambient gas

Carbon nanotubes can be synthesized by an arc discharge between graphite electrodes [(1)]. Bearing an extremely minute scale, nanotubes are attractive materials for applications such as field emitter, scanning microscope probe, *etc.* In this study, we prepared the nanotubes in different kinds of gases at various pressures in order to find the optimum conditions in which thinner nanotubes are quantitatively obtained without nanoparticles.

Nanotube synthesis was performed in a carbon arc device [(2)] filled with various gases (He, H_2, N_2, O_2, C_2H_2, and CO_2) at different pressures (3-100 kPa). The electric power was supplied between two graphite electrodes (both 10 mm in diameter, 99.998% in purity) by a dc power source with a constant current (50, 100, 150 A). The arc was operated for 30 s with an electrode separation of 1.5-2.0 mm. The cathode surface was observed with a scanning electron microscope (SEM; JEOL, JSM-6300). The deposits on the cathode surface exhibited two different parts in visual: an outer hard-shell with glossy silver color, and an inner soft-core in porous black appearance. As previously reported [(1)], nanotubes existed solely in the soft-core part.

Fig. 1 shows the SEM micrographs of the soft-core surface of cathode deposits prepared at 100 A. For He gas ambient, the ratio of the nanotubes to nanoparticles increased with increasing pressure, as examined by Zhang *et al.* [(3)]. Also nanotubes tended to elongate at 25 and 50 kPa, and the nanotubes became thick and shorter at higher pressures. For H_2, there was an apparent disappearance of nanoparticles than for He, as reported by Ando *et al.* [(4)]. At 25 kPa, longer nanotubes were obtained with very few nanoparticles. For N_2, larger nanoparticles adhered to the thicker nanotubes. For O_2, at lower pressure, many nanoparticles co-existed. However, at 25 Pa, almost no nanoparticles adhered to the nanotubes. For gases composed of carbon and hydrogen or oxygen (C_2H_2, CO_2), despite the presence of hydrogen or oxygen, the nanotubes were much less than those for pure H_2 or O_2 gases. These results indicated that pure hydrogen and oxygen ambient could decompose the nanoparticles effectively at 25 kPa.

As for arc current dependence, at lower current of 50 A, very few nanotubes and nanoparticles were obtained. When the current increased to 150 A, thicker nanotubes with mass of larger nanoparticles were produced and there was almost no dependency on gas types.

The authors would like to thank to Horizon Co., Ltd. for partial financial support and Dr. Toshiyuki Tsuboi for valuable discussions.

(Manuscript received February 18, 1999, revised March, 19, 1999)

References

(1) T. W. Ebbesen: "Carbon Nanotubes," *Annu. Rev. Mater. Sci.*, **24**, 235 (1994)
(2) H. Matsuo, I. Nakagawa, H. Takikawa & T. Sakakibara: "Fullerene production by carbon arc method in various gases," *Trans. Mat. Res. Soc. Japan*, **20**, 412 (1996)
(3) H. Zhang, D. Wang, X. Xue, B. Chen & S. Peng: "The effect of helium gas pressure on the formation and yield of nanotubes in arc discharge," *J. Phys. D: Appl Phys.*, **30**, L1 (1997)
(4) Y. Ando, X. Zhao & M. Ohkohchi: "Production of petal-like graphite sheets by hydrogen arc discharge," *Carbon*, **35**, 153 (1996)

Hirofumi Takikawa (Member) (See vol.119-A, p.189) E-mail: takikawa@eee.tut.ac.jp

Aristotle M. Coronel (Student-member) born in Manila, Philippines on October 24, 1972. He received B.S. and M.S. degrees in Electrical and Electronic Engineering at Toyohashi University of Technology, Japan in 1997 and 1999, respectively. He is currently employed at Asahi Chemical Industry.

Tateki Sakakibara (Member) (See vol.119-A, p.189)